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REPORT

**RADIO MICROPHONES:
operation at low frequencies**

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Summary

This report considers the use of low frequencies for radio microphones and talk back systems in Television Studios. Mutual interference with other apparatus in the studio, particularly with television cameras, rules out the possibility of using these frequencies. The risk of interference from numerous external sources would exist also.

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1. Introduction

The problems of successfully operating radio microphones in television studios are principally due to the non-uniform propagation conditions which invariably exist in this environment. At radio frequencies from Band I upwards the variability of the received field, with both the position of the receiving aerial and movement of the microphone is large and special measures have to be introduced to eliminate its effect.¹

Low frequencies in the range 50–200 kHz, have been suggested for use with radio microphones and radio talk-back systems because at these frequencies the studio dimensions are small compared to the wavelength and the probability of multiple zeros or deep minima in the field pattern becomes negligible.

The satisfactory operation of such systems would depend on the intensity of mutual interference with television cameras and other equipment. A short investigation has been carried out to assess feasibility.

2. General arrangement of assumed LF systems

2.1. Radio microphones

A maximum of four radio microphones may be required for one Television Studio and any system should be capable of accommodating this number of channels. It is assumed that a portable transmitter would be carried in the usual way by the performer and that it would be connected to a hand-held microphone. The transmitting aerial could consist of a multi-turn loop made up in the form of a belt worn round the waist of the user. The receiving aerial would consist of a single wire loop slung from the studio walls at a height of about 3 m above floor level, its output being distributed to the requisite number of receivers.

2.2. Studio talkback

The converse situation would be employed for studio talkback, the single wire loop being used as the transmitting aerial and the receiver (connected to the body loop) being carried by the user.

3. Coupling between transmitting and receiving loops

At vlf and lf the wavelength is longer than the studio dimensions and the maximum phase change over 30 m (the approximate length of a studio) would be only about 7° at 200 kHz.

The coupling between the receiving and transmitting loops is, to a first order, dependent on the magnetic induction field only and, because the expected phase variation is small, the predicted field strength and in-

duced emf can be derived directly from steady state field considerations.

The axial magnetic field at the centre of a square loop of wire is given by

$$H = \frac{I \sqrt{2}}{\pi R} N_1 \quad \text{AT/m}$$

where $2R$ = loop side length m.

I = loop current, Amps.

N_1 = number of turns

The emf induced in a small circular loop concentric with the large square loop is

$$= \frac{I \sqrt{2} \omega \mu a^2 N_1 N_2 \text{ volts}}{R}$$

where N_2 = number of turns in small loop

ω = $2\pi f$

a = radius of small loop, m

μ = permeability of free space = $4\pi \times 10^{-7}$

From these equations, it is found that a single wire loop, 30 m square, carrying a uniform current of 1.5 A produces a magnetic field intensity of 0.45 AT/m at its centre and at 100 kHz, an induced e.m.f. of 10 mV in a concentric circular four-turn loop having a diameter of 0.3 m. The coupling between the loops varies according to the position of the small loop within the larger loop. Fig. 1 shows how the coupling changes as the small loop

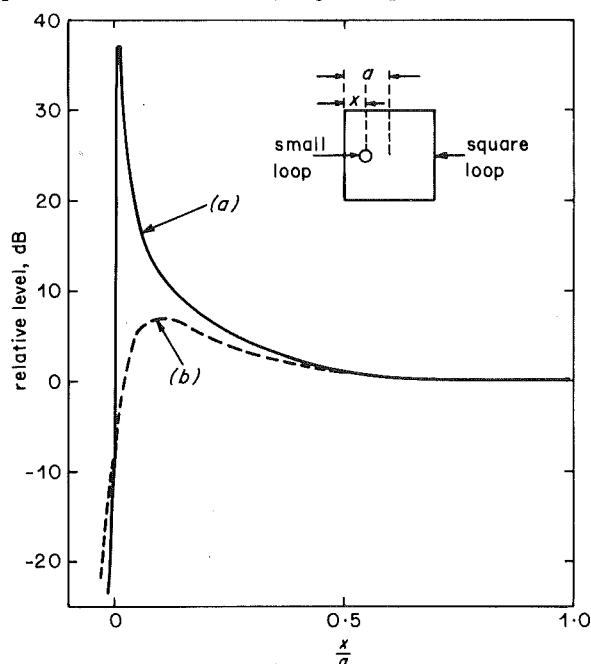


Fig. 1 - The relative coupling between horizontal loops
(a) small loop in the plane of the large loop conductors
(b) small loop 2 m below the plane of the large loop conductors

is moved in the plane of the large loop from the central position along a central axis towards one side.

In the studio, the large loop would be supported at a height of 3 m above floor level, the smaller loop worn by the user would be at waist height; approximately 1 m above floor level. The coupling, with loop axis parallel but with centres displaced both vertically and horizontally, is also shown in Fig. 1.

The field distribution in a studio would be modified by the presence of metallic materials such as studio equipment and floor re-inforcement. This aspect has not been investigated and measurements would be required to establish the modification of the coupling under these conditions.

4. Interfering noise sources

Interfering noise sources will affect the operation of both the radio microphone and talkback systems. They will not have equal effect because of the difference in the loop dimensions which would be used for the two systems. A number of measurements were made in the laboratory and a television studio to assess the levels of interference in the low frequency band 20–200 kHz.

4.1. Laboratory measurements

Levels of interfering signals occurring in the low frequency band were measured in the laboratory using a 6 m square single-turn wire loop aerial, spectrum analyser and a receiver. The measurements showed that considerable use is made of these frequencies; a large number of unidentified sources of interference were detected. Fig. 2 shows these interfering signals displayed by a spectrum analyser. A slow scan rate was used to obtain the display and some impulsive interference is also present.

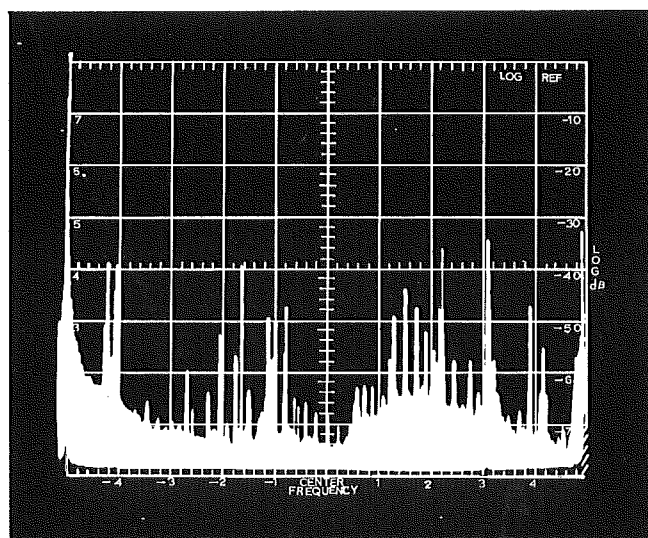


Fig. 2 - Spectrum of Interfering Sources

Horizontal Scale: 20 kHz per division, centre frequency 100 kHz
Vertical Scale: log.ref. corresponds to 7.1 mV (–30 dBm)

Table 1

kHz	Induced voltage	Magnetic field strength
	μV	(vertical component) $\text{AT/m} \times 10^{-6}$
16	79	17.2
20	79	13.9
31.5	4	0.45
48	7	0.51
57	5	0.31
62	5	0.28
69	71	3.62
77	25	1.14
80	22	0.97
84	28	1.17
95	3	0.11
110	5	0.16
113	5	0.16
117	5	0.15
123	9	0.26
127	25	0.69
132	50	1.33
137	28	0.72
152	9	0.21
164	140	3.00
186	14	0.26
192	2	0.04
200	178	3.13

Interfering Noise Sources

Table 1 shows some of the measured frequencies with their amplitudes. Much of the spectrum consisted of keyed data transmissions and difficulty was experienced in assigning a precise frequency to them.

4.2. Studio measurements

Interference signal measurements were made in Studio 8 at Television Centre during rehearsals. A receiving aerial consisting of a five turn balanced screened loop having a mean diameter of 600 mm was used in conjunction with a spectrum analyser to make the measurements.

The largest interference signals occurred at television line harmonic frequencies, the main source of interference being the television cameras themselves. The levels of interference, which it is assumed arise from the camera scanning coil currents, were measured with the receiving loop held 1 m from the camera head. These are tabulated in Table 2.

4.3. Effect of radiation on television cameras

In addition to the measurement of interfering signals which would degrade the radio microphone or talkback systems, it was also necessary to investigate the effect of the microphone/talkback transmissions themselves on television camera channels in a studio. A colour camera was subjected to an externally applied magnetic field. The camera head was encircled with a wire loop aerial

Table 2

kHz	μV	equivalent Magnetic Field $\text{AT/m} \times 10^{-6}$
31	490	1440
47	220	425
63	124	179
78	88	102
93	88	86
108	157	132
124	124	91
140	110	71
155	157	91
170	110	58
185	78	38
200	28	13

Magnetic field strength near to Television camera

driven from a r.f. signal generator. Table 3 shows the estimated value of magnetic field which gave a just perceptible interference pattern on the camera 'red' channel (the channel having the greatest sensitivity). Least interference was produced when the frequency of the applied magnetic field was centred between line harmonic frequencies. The level of interference tended to increase with increasing frequency. Measurements were not made at frequencies below 50 kHz.

5. Discussion of results

As stated earlier, the importance of the various forms of interference differs according to which of the two systems of communication is under consideration.

5.1. Radio Microphones

For the radio microphone system a large single wire loop would be used as a receiving aerial, and because its dimensions would be greater than that of the test aerial, the induced interference levels from external sources would be approximately 30 dB greater than the values given in Table 1. At 100 kHz the interfering field corresponds to 0.08×10^{-6} AT/m, shown as -70 dB in Fig. 2. Reference to Fig. 2, shows that little spectrum is available where the interference would be less than -70 dB, and this does not include interference at line harmonic frequencies.

It is not possible to derive the amplitude of the induced voltages at line harmonic frequencies from the results of measurements taken in the Television Studio, since these would be dependent on the position of the cameras within the studio area. It is expected that these voltages would be substantial and would certainly present a problem in designing a radio microphone system.

A separation of greater than 60 dB between wanted and unwanted signals would be required for a high quality radio link using amplitude modulation. The wanted signal needed to give a satisfactory margin above the

0.08×10^{-6} AT/m interference level at 100 kHz should be achieved with the transmitter positioned at the edges of the studio area where the loop coupling is lowest; (see curve (b) Fig. 1) and for a 30 m square single turn receiving loop the induced voltage with the transmitter situated at the centre of the studio would need to be 180 mV. Calculation shows that to establish this voltage when using a four turn transmitting loop having suitable dimensions to fit the users waist, a drive voltage of approximately 200 V would be required to produce the necessary loop magnetising current of 27A. This is obviously beyond the capability of a small battery driven transmitter and even if this could be arranged would present a considerable hazard to the user.

5.2. Studio talkback

The requirements for high quality are not as stringent for talk-back as they are for radio microphones and probably a separation of 40 dB between wanted and unwanted signals would be adequate.

Table 3

Frequency	AT/m
51.8	0.338
54	
57.6	0.338
62.8	0.17
67	0.068
70	0.338
73	0.236
78.1	0.020
82.8	0.050
85.8	0.202
88.8	0.101

Magnetic field strength to produce perceptible interference on the red channel of a Television Camera

The small loop aerial would be used for the talk-back reception and the magnetic field of external sources would be less than 3.6×10^{-6} AT/m. At line harmonic frequencies, when the loop is in close proximity to an operational camera, the magnetic field strength could reach approximately 180×10^{-6} AT/m.

The required magnetic field strength to meet a 40 dB separation allowing for the variation of field over the studio area would be 0.001 AT/m at frequencies centred between line harmonic frequencies and 0.045 AT/m at line harmonic frequencies.

During studio operations, the camera may be used at various heights above the floor and it would certainly be possible for a camera to come in to close proximity to the transmitting loop. In regions of the studio near the transmitting loop conductor the magnetic field could be more than 30 dB above that at the loop centre, and a camera situated in this position would be subjected to an external magnetic field which would be larger than or comparable to the measured values which gave perceptible

interference on the test with the colour camera (section 4.3.). The considerable risk of interference being induced in camera circuits must preclude the use of low frequencies for talk-back applications.

6. Conclusions

The investigation has shown that insuperable difficulties would be experienced in trying to engineer a satisfactory low frequency system for either radio microphones or talkback. Apart from interference effects on cameras,

transmission at those frequencies may well cause interference on other studio equipment, of which no account has been taken in this investigation. It must be concluded that these frequencies are unsuitable for either microphone or talk-back circuits in a television studio.

7. Reference

1. THODAY, R.D.C. 1973. Radio Microphones: propagation characteristics in television studios. BBC Research Department Report No. 1973/3.